DEVELOPING AN ACTIVE GPS STATION BASED ON LOW-COST GPS INSTRUMENTATION[1] (UPP GRANT VOTE 71147)

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BIOGRAPHY

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ABSTRACT

Global Positioning System (GPS) is a satellite-based positioning system globally used for position and velocity determination as well as for precise timing. A GPS Active Station is a set-up in which a GPS receiver located on a known station is operated in a continuous manner, collecting data transmitted by the GPS satellites. This setup is also known as Continuous Operating Reference Station (CORS). Normally connected in a network of several other CORS, these stations serve multi applications. A small research has been on going in UTM to establish a GPS active station, based on low-cost GPS instrumentation. The main objective of this project is to acquire and enhance the technology in operating and maintaining of such station. This paper describes the hardware configuration of the proposed station, as well as the necessary software to be developed in order for this station to be operated continuously in an automated manner.

INTRODUCTION

GPS active station, normally in an array of network, has become an important element of enhancements in GPS works and applications. A typical configuration of an active GPS station would consist of a GPS receiver (normally dual-frequency top-of-the-line type) and a computer. The receiver would be placed on a station with a pre-determined coordinate, while the computer is used for I/O operations, data pre-processing and storage. The operation would be continuous (hence called Continuous Operating Receiver Station, CORS), tracking all-available GPS data around the clock. The collected data will be analyzed and archived. It could also be transported to other site through radio link or modem.

An active GPS station could serve a variety of purposes. In the most rudiment application in surveying, the active station is to supply 'the other side of the data' for single receiver GPS operators, to enable them to process their data in a relative mode. Operations of such a station should be autonomous with minimum

[1] SEMINAR ON ELECTRICAL, ELECTRONICS, AEROSPACE, INFORMATION TECHNOLOGY AND TELECOMMUNICATIONS
12 November 1997, SOFITEL Hotel, Senai, JOHOR DT.

operator interference. For such, it has to have flawless I/O operations and necessary software for data analysis and management.

Networks of GPS active stations can be of regional or global coverage. Examples are the Canadian GPS Active Control Station (Delikaraoglou et al., 1990), for the regional scale and the Cooperative International GPS Network (CIGNET) as well as the International Geodynamic Services Network (IGSN) of the global scale. The latest plan for a network of active GPS stations in Malaysia is the The SistEm Jaringan GPS AuTomatik (SEJAGAT) Network by the Department of Surveying and Mapping. This would be the first active GPS network for Malaysia.

A project is currently being undertaken in UTM to establish an active GPS station. The aim of which is to get the necessary technology and experience in operating and maintaining such a station. The hardware is based on a low-cost GPS engine.

Four immediate objectives of this project are as follows;

1. To set-up an active GPS station based on low-cost GPS instrumentation
2. To develop GPS data quality measures
3. To develop a GPS data management facility
4. To make available GPS data to users

The other by-product of this project is to set-up a GPS receiver with flexible operating capabilities to be use for further GPS data processing experiments, such as;

- Unrestricted data collection procedures
- Tailor-made spec for data observation

This paper describes the hardware configuration of the proposed station, as well as the necessary software to be develop in order for this station to be operated continuously in an automated manner.

HARDWARE REQUIREMENT FOR AN ACTIVE GPS STATION

Commercial GPS active stations are available through several GPS hardware vendors. Most of them are based on the 'high-end' GPS hardware type, usually a dual-frequency receiver (hence the most expensive ones). It also normally comes as a package of others such as radio transmitter, to serve as a reference station for Differential GPS (DGPS) applications. The software is of 'proprietary-type' which users has little or no input, other than using the options given. Operations are most of the time carried out according to the manual supplied by the vendor.

Low-cost GPS instrumentation

For this project, the GPS hardware to be use is a GPSCard. This is a PC-based GPS receiver of which is to be housed in a PC that will also controlled the I/O procedures. Another option would be the OEM-type GPS receivers. These receivers are considered as GPS 'engines' or 'sensors' that are normally used by system-integrators (Subari, 1997). The selected receiver will have characteristics as follows;

- 12 channel tracking – the receiver is capable of tracking most of the available satellites on the local sky at all time (for equatorial areas like Malaysia, that would be the maximum number of satellite available)
- C1, L1, D1 data measurement – the receiver is capable of outputting the C/A-code data (the C1), the carrier phase data as well as the Doppler data on the L1 frequency (the L1 and the D1).
- 10 Hz data rate – most low-cost 'navigation' type receivers has only 1 Hz data output.

The PC could be any of the typical IBM-compatible one with math microprocessor.

ERROR MITIGATION FOR AN ACTIVE STATION

Being installed permanently on a fixed site, two issues are of interest, namely the multipath calibrations and the known station position.

<u>Multipath callibration</u>

Multipath is a major source of data corruption. This is a phenomenon in which signals from the GPS satellites being reflected by some objects nearby the GPS receiver would contaminate the direct signal being observed by the receiver's antena. Multipath has a repeating nature, following the repeatition of the satellite's geometry on the sky. On a permanent installation, the multipath effect for each satellite can be modelled (assuming the sources of multipathing remain the same e.g., buildings, walls, etc.) hence, it is possible to have it 'corrected'. A better option would be to have a multipath-model file for a data span, for the user's option in the data processing.

Known station position
The receiver's position will be known accurately through some survey campaigns, connecting it to some well-established GPS networks. With this known, certain data quality analysis could be made.

DATA MANAGEMENT

The data management software would perform the following functions;

Data keeping and data archiving
Observed GPS data will be keep in two datafiles, Observation datafile and Navigation datafile. Observation datafiles will contain GPS data collected over a 24-hour period (0:00:00 to 23:59:30 GPS Time, Local Time – 8 hours). Navigation datafiles will contain Broadcast Ephemeris data observed for all satellites observed in the same period. For space-saving purposes, datafiles will be compressed before being archived. Data will be archive daily in the RINEX format (version 2).

Data identification (tagging) and extraction
For data identification purposes, the following naming convention will be used;
"SSSSDDDT.YYZ"
where:
- "SSS" refers to site 4 character ID e.g. UTMA
- "DDD" refers to the day of the year
- "T" refers to data type, O for observations and N for navigation (broadcast ephemerides)
- "YY" is the year e.g. 97
- "Z" indicates that the files is in compressed format

Data access and dissemination
Initially, the general public could obtain the data through mail order, in the future an FTP site will be setup for 24 hours accessibility (charges?)

DATA QUALITY CONTROL

Before the data is archived, several data quality check-up procedures will be carried out. Two types of programs are needed for this purpose;

- Data conversion and formatting – this program would include routines for data translating, data 'reconstruction' and data formatting. Observed GPS data will be in a 'propriety-binary' format, hence a routine is needed to convert this data to an ASCII output. The data reconstruction would only for the C/A-code data, which normally comes in the 'milli-second fraction', format. The ambiguous milli-second part would need to be determined from the known satellite's position and the approximate receiver's position. Finally a routine is needed to convert this data to an internationally accepted RINEX version 2 format. An option can also be included in this state to compute receiver clock error, hence applying observation time tag corrections to the data.

- Data Quality Analysis – This program would include routines for data quality indicators, cycle slip detection and data QC scaling.

  Data Quality Indicators
  This routine will checks on data error, data breaks, and data offshoot. Several statistical procedures will be employed such as W-test for data snooping for outlier detection, utilising the normalised residuals of the observations (Mertikas and Rizos, 1997).
  Signal strength or Signal to Noise (S/N) ratio which gives indication of the strength of signal recorded, normally in the scale of individual receiver make can

also be use for this purpose. The larger the scale indicated the stronger the received signal (i.e., the better quality of the measurement?).

Cycle slips detection

Carrier phase data are susceptible to cycle clips, due to signal lost or disturbances. This would results in a discontinuity of the data. Use of low-order polynomial to fit the time series of the carrier phase data – the residuals after fitting is screened for the cycle slips (magnitude of several cycles). Or use of Kalman filter to forward predict the observable – the difference between the predicted and measured tested observable is then used for cycle slip detection. Note that the cycle slip will NOT be corrected.

Data QC Scaling

Finally, a scale of 1-9 will be given to the data, indicating the overall quality. This quality scale will give rough indications to the users on the expected quality of the data span. A QC scale of 9 would indicate that the overall data should be good while a QC of 1 would indicate otherwise.

NOTE: Raw observation data will not be tampered. Only indicators will be provided for each data span with a QC Scale to indicate the overall quality of the data.

GPS ACTIVE STATION: OPERATION AND MAINTENANCE

The operations of the active station would be automated with minimum operator intervention. For this, the system should have fault detection capabilities to acknowledge any discrepancies from the normal operating conditions. A system diagnostic routine will be needed.

SUMMARY AND FUTURE PLAN

A project to setup a GPS active station is currently undertaken in UTM. Apart from acquiring the hardware setup, the software part is also a major part in this project. With this project it is hoped that the technology in operating and maintaining a GPS active station will be acquired. Furthermore, a low-cost system will be setup.

Future development would consider making this active station a DGPS station, capable of computing and transmitting GPS differential-corrections to other users. This would require an incorporation of data transmission module. A likely candidate would be through cellular phone system.

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